Statement of Work

Carbon Phenolic Thermal Protection Systems for NASA's Atmospheric Entry Heat Shields

Carbon Phenolic Development Project

July 25, 2011

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

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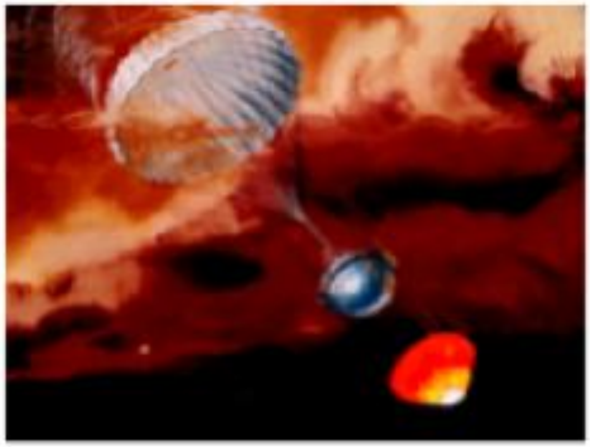
1.0 INTRODUCTION

1.1 GENERAL INFORMATION



To date NASA has utilized carbon phenolic (CP) heatshields for its most demanding reentry missions, Pioneer Venus (PV) and Galileo (Jupiter). These heat shields consisted of a Tape Wrapped Carbon Phenolic (TWCP) frustum and a Chop Molded Carbon Phenolic (CMCP) spherical nose. TWCP has uses beyond NASA thermal protection system (TPS) requirements, such as in rocket nozzles etc., however CMCP is basically a NASA-unique CP architecture that has very few other applications. It has been more than 30 years since NASA has flown a mission requiring CMCP TPS materials and therefore industry's capability to support CMCP fabrication is unclear.

NASA has a significant interest in CP materials for future planetary missions. The recently released Decadal Survey findings, show that the Planetary Science community has prioritized missions to Venus, Saturn and the Ice Giant Outer Planets such as Neptune. In addition, a Mars Sample Return (MSR) mission is being considered that will require a highly-reliable TPS in order to meet the planetary protection requirements upon Earth return. Previous MSR mission studies have baselined CP as heat shield TPS material. The Decadal survey findings can be found at:

http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412

Mission and/or technical assessment studies in support of the Planetary Sciences Decadal Survey can be found at:

http://sites.nationalacademies.org/SSB/SSB_059331

Specifically, mission studies of interest related to this RFP are:

1) Venus Mobile Explorer Mission Concept Study
2) Venus Intrepid Tessera Lander Concept Study
3) Saturn Atmospheric Entry Probe Trade Study
4) Saturn Atmospheric Entry Probe Mission Concept Study
5) Uranus and Neptune Orbiter and Probe Concept Studies

6) Mars Sample Return (MSR) Orbiter Mission Concept Study (Including Sample Return EEV)

In a series of white papers,[1,2,3] the TPS community has proposed that the primary candidate for these missions is the heritage FM 5055 carbon (heritage carbon phenolic or HCP) that was used for Galileo (Jupiter) entry probe and the FM 5055 uses carbon cloth derived from Avtex rayon. Pioneer Venus (PV) utilized similar TWCP and CMCP materials however a different rayon precursor was utilized in the manufacturing of the carbon cloth.

Due to the limited supply of the Avtex-based carbon cloth, an updated CP material based on non-Avtex rayon fibers will be required in order to implement the proposed missions. There may be sufficient heritage rayon for a single mission depending upon its size and reliability requirements but not for multiple missions.

Each of the missions identified in the Decadal Survey will require robust heat shield TPS with sizes ranging from 1 to 3.5 meters in diameter. However, it has been nearly 30 years since NASA has involved itself with planetary missions requiring the use of CP heat shield materials. One of the objectives of this RFP is to better enable NASA to respond to the Decadal Survey recommendations, by assessing industry's capability to provide CP heatshields and understand technology/processing advances (or deficiencies) in CP manufacturing.

In order to find a cost effective, sustainable and robust TPS solution that supports both near and long term missions, NASA seeks to assess existing industrial capabilities. NASA also seeks to understand improvements to CP manufacturing approaches that may have been developed, since the Galileo heat shield was fabricated, and if these approaches can meet NASA's requirements. Such information will allow NASA to plan a cost-effective development program.

The intent of this RFP is to obtain data from industry in order for NASA to assess and prepare a CP manufacturing and maturation plan to mature CP technology to technology readiness level (TRL) 6 in time to support the proposed missions[4]. Independent of this program, NASA may select some of

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[1] White Paper to the NRC Decadal Survey Outer Planets Sub-Panel
[2] White Paper to the NRC Decadal Survey Sub-Panels Mars and Outer Planet Satellites
[3] White Paper to the NRC Decadal Survey Inner Planets Sub-Panel
[4] •To achieve TRL 6, need to demonstrate system performance in relevant environment
 –Need to fabricate TW and CM CP to NASA acceptance specifications using currently available materials (carbon fabric, resin, filler, etc.) and modern equipment (full scale)
•TW and CM material must be full scale, using identical equipment for flight units
 –Full scale units (MDU) must be inspected and accepted as though they were for flight
 –Thermal and material property test coupons must be machined from MDUs
 –Test all components (TW, CM and gap design) in relevant environment to verify performance (thermal performance to be verified via arcjet testing, to be conducted by NASA)

these Science Missions (as referenced previously) on a competed basis, such as under the Discovery and/or New Frontier proposal processes. These competed mission proposals may have their own CP development approaches constrained by the proposed architecture and mission design specifics and may be independent of this technology maturation plan.

For high-risk missions such as a Mars Sample Return, NASA seeks to manufacture heat shields made of “heritage carbon phenolic,” in other words try to match the heritage materials as well as the heritage manufacturing processes to the greatest extent practical. Due to the limited supply of the heritage carbon fabric (Avtex- rayon based carbonized fabric referred to as CCA-3 1641B) that NASA has in its inventory, most, if not all, will likely be utilized to support the MSR mission.

Given the heritage material supply issues and that CP, and CMCP in particular, have not been manufactured for a flight mission since Galileo, NASA has two immediate objectives for CP development. One is to re-establish the heritage CP manufacturing capability (or as close to it as possible, utilizing a minimum amount of the CCA-3 1641B fabric). The second is to establish an alternate to the heritage CP manufacturing capability (alternate rayon precursor and possibly alternate processes). The goal is to mature both of these objectives to TRL 6 in the next 5 years, depending on funding opportunities and mission needs. Results from the development effort may feed into near term missions, if they are selected, but it is primarily intended to support the longer-term missions with heritage (baseline) or alternate CP. Given that missions requiring CP heat shields may have many years between flights a key aspect to consider for alternate CP development is long-term sustainability of the materials availability and manufacturing capability.

This SOW describes the requirements in support of the initial planning phase of CP heat shield development for future NASA missions. NASA’s long-term goal is to have a well-established industrial capability ready and available to manufacture heat shields for its multiple exploration missions across the next several decades. What NASA needs is data to understand risks involved in current manufacturing capabilities that include tools, machinery, processes and expertise, sustainability, and, if capabilities have atrophied, what would it take to revive the capabilities. To this end, information is requested from vendors that can help NASA understand their current capability to provide all elements of entry grade (as opposed to nozzle grade) carbon phenolic including raw materials, manufacture of test articles, material testing capabilities, full-scale manufacturing demonstration units (MDUs), and eventually flight hardware. This exercise is critical in the development of processes and vendors qualified to provide flight hardware.

As stated in the RFP, it should be understood that NASA's award of this contract is only for the deliverables defined herein, and there is no explicit or implied commitment for future procurements in this action.

1.2 SCOPE AND OBJECTIVES

This Statement of Work (SOW) defines the data NASA needs to support the revitalization of materials and concepts for NASA missions requiring heritage and alternate carbon phenolic heat shields and the requirements for the procurement of chop molded carbon phenolic (CMCP) coupons.

Responses to this RFP should address the specific questions outlined below. Responses must also address the more detailed narrative of requirements given in the description of DR-001 Detailed Heat Shield Implementation Plan in Section 6.0 Data Requirements.

1. What is your past experience in providing entry grade carbon phenolic heat shields including those made from FM 5055G HCP tape wrapped or chop molded (and/or materials manufactured within the FM5055 family)?

2. What is your current capability in heat shield relevant TPS manufacturing?
    i. Personnel experienced in making reentry grade CP (number of personnel and number of years of experience)
    ii. Associated product assurance certifications and processing equipment necessary to do so
    iii. Certifiable process procedures and specifications
3. Figure 3 shows the design of one of the Pioneer Venus probes' CP heat shields, consisting of a CMCP nose cap and a TWCP frustum. This probe had a diameter of 1.4m (~56 inches). NASA has interest in missions that would look at scaling this design from 1m max diameter up to 3.5m max diameter. Within this size range what capabilities do you currently have for CP manufacturing (e.g., Do you have the mandrill, tape wrapping equipment, etc., in place or do you need to design and acquire it? How long and how much funding will it take)? Up to what scale and cone angle could you manufacture with existing infrastructure? What challenges do you foresee with scale-up of the CMCP manufacturing? How do you plan to mitigate these challenges? Are there alternatives to the traditional monolithic CMCP billet that you propose to utilize?
4. Do you see any difficulty in manufacturing a TW heat shield for a 60 deg conical section with a 20 deg ply angle? What experience do you have in tape wrapping NARC, ENKA, C2 or Lyocell? Can you make FM 5055G like tape wrapped test coupons of ~ 6 cm thickness?
5. Can you make FM 5055 chop molded test coupons of ~30 cm thickness and 350 cm diameter? If you do not have the facilities to make CM billets of this size now, describe the capability you currently have and the cost and schedule required to upgrade your facilities.

6. What are the sources of your raw materials and how would you ensure their traceability to those of HCP?
7. What is the probability of providing sustained supplies of the raw materials, and what are the alternates? What data do you have that verifies that the CP manufacture from the proposed alternate raw materials will provide the same performance as CP manufactured from the heritage raw materials?
8. Can you make full scale MDUs (1 to 3.5m diameter and 60-degree cone angle)? Describe the specific equipment that would be utilized for this task. The full scale MDU will be made of Chop Molded and Tape Wrapped parts. If you are unable to make one of the two CP parts, would you look for a subcontractor and who would be your sub?
   i. If the equipment is not currently running, what would be required to restore operational capability?
   ii. If you do not have operators, currently trained, what would it take to get them trained?
   iii. Do you need to scale up the equipment? If so, what would certifying the scaled equipment mean in terms of cost and schedule?
9. Describe your experience making flight hardware (see Appendix A). If you have only provided elements of flight components, please specify.
10. What methods have you used to attach CP to various substructures? To which substructure materials have you attached them?
11. If you have an alternate CP to HCP, please describe why you would recommend it. Why do you believe its performance would be comparable to HCP? The alternate CP could only consist of
   i. alternate raw materials utilized in heritage tape wrapped or chop molded configurations
   ii. and/or it could consist of alternate architectures or fabrication techniques to tape wrapped and/or chop molded configurations.

1.3 DELIVERABLES

1.3.1 Data Deliverables (Required)

A description of the data deliverables required in this procurement is provided in Table 1 with descriptions and required test reports shown in the Data Requirements, section 6, of this document.

Table 1 – Data Requirements List

DR #	Title	Initial Delivery	Submission Frequency
DR-001	Preliminary Heatshield Implementation Plan (PHIP) and Detailed Heatshield Implementation Plan (DHIP)	PHIP with proposal	• Update 6 weeks after award • Final DHIP 1 month after update
DR-002	Updated Material Acceptance Specification	Draft 1 month after award	No later than December 15, 2011

1.3.2 Hardware Deliverables (Option)

A description of the hardware deliverables requested as an option in this procurement is provided in Table 2, with specimen descriptions shown in Section 5 of this document. For these coupons (if selected) the fabrication of all items described in Table 2 should be priced as an option using commercially available MX-4926 molding compound (ENKA fiber, SC-1008 resin, carbon filler – chopped in ½-inch squares).

Table 2- Hardware Requirements List

HR #	Sample Type	Number of Samples	Delivery Date
HR-01	CMCP Nose Billet	1	No later than December 15, 2011
HR-02 (additional option)	CMCP Nose Billet	1	No later than December 15, 2011

All delivered specimens must be accompanied by a Material Safety Data Sheet (MSDS) for all materials used in manufacturing the specimen (reference FAR clause 52.223-3 Hazardous Material Identification and Material Safety Data (Alt I).

2.0 APPLICABLE DOCUMENTS

All applicable documents, which will form a part of this RFP, are listed herein. The applicable version shall be the current version at the time of contract award. In the event of a conflict between applicable documents and the contents of this SOW, the SOW shall take precedence. These documents are ITAR restricted. See instructions in the RFP on how to access these documents.

- GE Spec S0060-01-0076, 3 November 1978
- GE Spec for Prepreg: GE R6537 Carbon Fabric Materials (prepreg).
- MSFC-SPEC (FM5055B)

3.0 TASK REQUIREMENTS

3.1 GENERAL

NASA's Contracting Officer Technical Representative (COTR) will serve as the primary point of contact between NASA and the Contractor for all technical and programmatic issues related to this SOW. The NASA Contracting Officer (CO) will serve as the primary contact for all contractual issues.

a) The Contractor shall provide management of all resources, schedule, procurement, quality control, and documentation control to deliver the services and products required.
b) The Contractor shall designate a single individual who will be given full responsibility and authority to manage and administer all aspects of the work specified in this SOW, and ensure that all objectives are accomplished within schedule and cost constraints.
c) The Contractor shall designate a single individual who shall serve as the point of contact with the COTR for all technical and programmatic aspects of the contract.
d) The Contractor shall designate a single individual who shall serve as the point of contact with the CO for all contractual aspects of the contract.
e) After the contract is in place, the COTR will determine the frequency and the method for progress reporting. We anticipate bi-weekly reporting.

3.2 SCHEDULE

The anticipated schedule for conducting this procurement is provided in Table 3 for your information. These dates are projections only and are not intended to commit NASA to complete a particular action at a given time.

Table 3 – Proposed Task Schedule

Task	Date
RFP Release	July 26, 2011
RFP response with PHIP*	August 26, 2011
Anticipated date for Contract in place	September 2, 2011
Updated Heatshield Implementation Plan	October 17, 2011
Updated Material Acceptance Specification	October 17, 2011
NASA approves final Acceptance Spec and ATP for coupon fabrication.	October 28, 2011
Final DHIP	November 15, 2011
Optional CMCP Coupons	December 15, 2011

- PHIP due as part of proposal in response to this RFP.

3.3 NASA XEROX DOCUSHARE COLLABORATIVE ENVIRONMENT

The NASA XEROX DocuShare collaborative environment will be the primary means of sharing, reporting, collecting, recording, and accessing project information between NASA, the TPS Contractor, subcontractors and authorized personnel connected with the CP development project. Once awarded, the Contractor will work with the NASA COTR to establish access to XEROX DocuShare .

3.4 SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

3.4.1 Materials Delivery Documentation

a) The Contractor(s) shall provide copies of test specimen Materials Safety Data Sheets for all TPS materials delivered under this contract.

b) The Contractor(s) shall provide copies of test specimen inspection documentation.

3.4.2 Process Assessment

The Contractor(s) shall identify the process areas that could impact the quality of the delivered product such as voids or other manufacturing defects, raw material availability, concerns associated with subcontractors, etc., whose occurrence can cause system failure, hazardous occurrence or otherwise impact the quality of the products to be delivered. The assessment shall be used in developing inspection and/or repair plans and identifying items requiring special handling, testing, or procurement controls. The assessment shall be initially addressed in the proposal but it is expected that it will be a continuous process and shall be updated as required throughout the life of the contract.

4.0 ACRONYM LIST

ARC	Ames Research Center
CM	Chop Molded
CMCP	Chop Molded Carbon Phenolic
CO	Contracting Officer
COTR	Contracting Officer Technical Representative
CP	Carbon Phenolic
DHIP	Detailed Heat Shield Implementation Plan
DR	Data Requirements
DRL	Data Requirements List
EDU	Engineering Development Unit
EEV	Earth Entry Vehicle
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
HCP	Heritage Carbon Phenolic
HRL	Hardware Requirements List
HS	Heat Shield
ICE	Integrated Collaborative Environment
LDDU	Local Design Development Unit
MDU	Manufacturing Development Unit
MSDS	Material Safety Data Sheet
MSR	Mars Sample Return
NASA	National Aeronautics and Space Administration
NDE	Non-Destructive Evaluation
NIST	National Institute of Standards and Technology
OML	Outer Mold Line
PHA	Preliminary Hazard Analysis
PHIP	Preliminary Heatshield Implementation Plan
PV	Pioneer Venus
QMS	Quality Management System
RFP	Request for Proposal
RMP	Risk Management Plan
SDR	Systems Design Review
SE	System Engineering
SOW	Statement of Work
SRM&QA	Safety, Reliability, Maintainability and Quality Assurance
TBD	To Be Determined
TIM	Technical Interchange Meeting
TPS	Thermal Protection System
TW	Tape Wrapped
TWCP	Tape Wrapped Carbon Phenolic
V&V	Verification and Validation

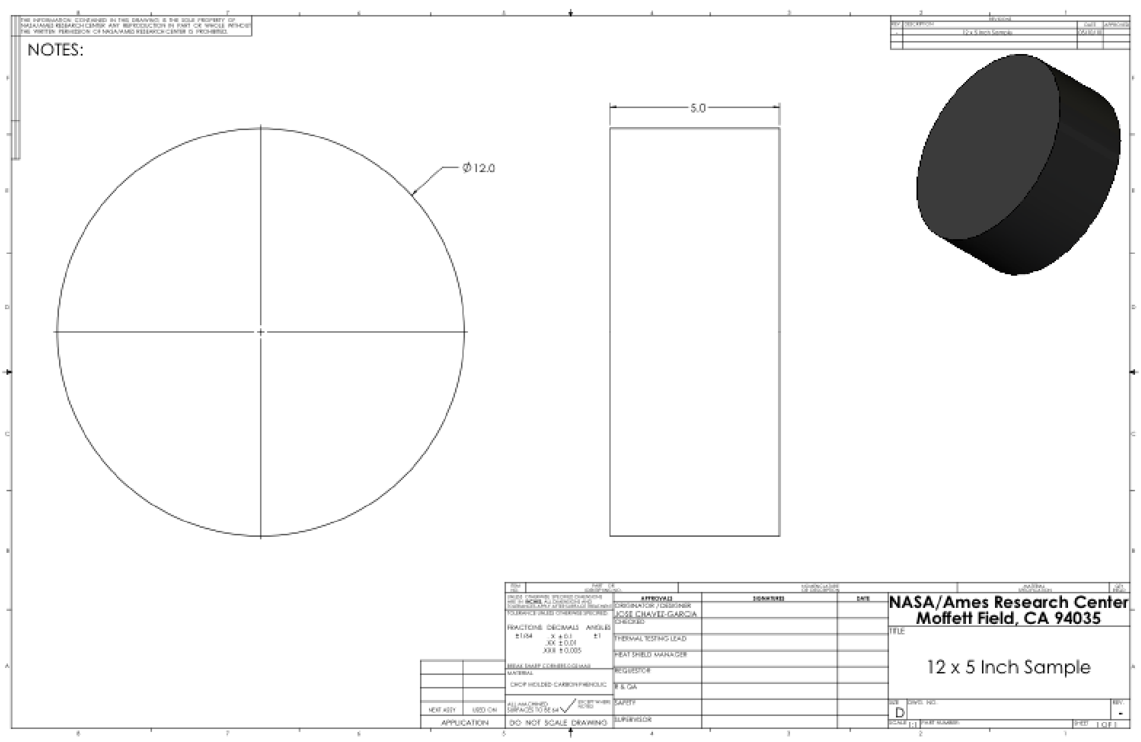
5.0 HARDWARE REQUIREMENTS (PRICE AS OPTIONS)

The Contractor shall deliver the following hardware deliverables as specified in the Statement of Work (SOW). For the items described in this Hardware Requirements List (HRL), all communication between the Contractor and NASA shall be initiated with the Contracting Officer's Technical Representative (COTR), unless otherwise directed in the contract.

1.0 Test Articles and Coupons

Coupon samples of chop molded carbon phenolic will be used by NASA to evaluate physical, structural and thermal properties performance of modern day chop molded carbon phenolic TPS. Test articles and coupons required are summarized in the Table below and the following drawing.

HR #	Sample Type	Number of Samples	Delivery Date	Fabrication Procedure
HR-01 (option)	CMCP Billet	1	No later than Nov 30, 2011	As required to meet properties specified in Appendix A Section 3.2.2.2.1.2
HR-02 (additional option)	CMCP Billet	1	No later than Nov 30, 2011	As required to meet properties specified in Appendix A Section 3.2.2.2.1.2



Hardware Coupon Dimensions

2.0 Instrumentation

No Instrumentation is requested as part of this solicitation.

3.0 Required Testing and Documentation

Each test coupon shall be accompanied by the traceability documentation (including unique article identifier, material lot or batch ID, etc.) and certification of inspection and compliance with the NASA/Contractor agreed upon acceptance specifications as described in Data Requirement 002.

The Contractor shall provide the following minimum information in tabular format with delivery of their specimens to NASA:

1. Material coupon actual weight
2. Material coupon actual dimensions
3. Material coupon density
4. Material coupon resin content
5. Material coupon residual volatiles
6. Documentation of any non-conformance or other out of the ordinary conditions.

4.0 Optional Testing and Documentation

The Contractor shall price the following inspection/testing as an option:

1. X-Ray CT scan of billet
2. Material coupon tensile strength
3. Material coupon modulus

For numbers of tests for material properties quantities should be representative of what (if any) is typically used for tag end testing. Contract shall provide an estimate of the amount of material remaining after sectioning to produce material property test coupons. The contractor shall endeavor to maintain as much of the billet continuous as possible. The contractor shall provide details of the types of testing to be conducted (ASTM standards or the like). The contractor shall specify if the testing is to be conducted in-house or by utilizing a third party. If a third party is to be utilized the contractor shall identify whom they propose to use.

5.0 Applicable Documents

The Contractor shall use the following documents as guidelines for material acceptance:

- FM 5055 Material Acceptance Specification (Appendix A)

However, the Contractor shall provide a draft version of DR-002 (Updated Material Acceptance Specification) for NASA review and acceptance prior to fabrication of the CMPC billet(s).

6.0 DATA REQUIREMENTS

1. **DR NO.**: DR-001

2. **TITLE**: Detailed Heat Shield Implementation Plan

3. **DATA PREPARATION INFORMATION**:

3.1 **SCOPE**

The Detailed Heat Shield Implementation Plan (DHIP) captures, for the government, a clear and comprehensive plan documenting the approach the Contractor intends to use to execute the manufacture, testing, NDE evaluation, acceptance criteria, assembly and delivery of flight ready heat shields. The DHIP should not only cover the plans regarding the final flight heat shield but also cover the cost, schedule and key milestones for each step that are necessary in the development of flight heat shields, starting from the end of the present contract and any continued development to support scale up and certification, through the fabrication of flight heat shields. It should notably include the development of Engineering Demonstration Units (EDU), required changes to equipment and infrastructure (including estimated costs) necessary for fabricating heat shields 1.5 to 3.5 m in diameter, and an approach for achieving certification of the flight articles. It shall also specify new equipment and cost for manufacturing of the EDU, including such items as new tape wrap mandrels and alternate molds for CMCP that conserve prepreg material usage, if utilized. The DHIP should provide a start-to-finish estimate for the amount of prepreg required to fabricate TWCP and CMCP parts, including in the estimate machining wastage and material that would be removed for “tag-end” testing. Drawings of the 4 heat shield sizes to be estimated are shown below and can be found on the Xerox DocuShare website in a folder entitled “Notional Heat Shield Designs”. The DHIP should also specify the costs to the government for sustaining the manufacturing capability at the contractor’s site during those times between the builds of flight heat shields for NASA missions, addressing how the contractor plans to maintain this capability once developed to mitigate the risks associated with low flight rates. The DHIP should also discuss any risks including quality control and assurance issues associated with long-term storage of raw materials and finished parts.

The submission of the PHIP shall be provided with the initial proposal and need not have complete cost and schedule data. However, the PHIP should be comprehensive enough to allow the government to evaluate the vendor qualifications for producing an MDU, EDU and eventually flight hardware. A finalized version with detailed cost and manufacturing schedules is due at the end of contract. ***If the vendor’s capabilities do***

not encompass the manufacture and delivery of complete MDUs, EDUs or flight hardware, they are encouraged to provide a partial PHIP response that allows NASA to evaluate their potential for future contributions, e.g., (i) how could the vendor deliver a CMCP nose part, meeting the specifications described herein, (ii) fully machined TWCP frustum ready for integration by a prime contractor, or for NASA to perform the integration function.

3.2 APPLICABLE DOCUMENTS

- FM 5055 Material Acceptance Specification (Appendix A)

3.3 CONTENT

An exploded view of a typical NASA blunt sphere-cone entry probe is shown in Figure 1. Of interest in this RFP is the primary heat shield, which consists a rigid aero-shell structure and attached TPS - a frustum and a nose cap.

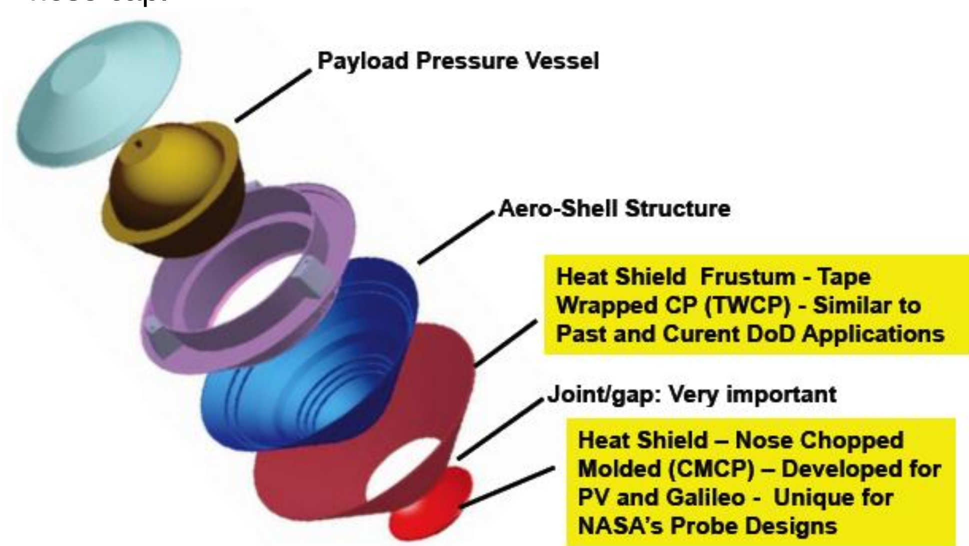


Figure 1 - Exploded view of a typical blunt sphere-cone entry probe.

The frustum is fabricated from tape wrapped carbon phenolic (TWCP) and the nose cap from chop molded carbon phenolic (CMCP). Future blunt-cone heat shields required by NASA with dimensions 1.5 to 3.5 meters base diameter (scaled Pioneer Venus probe) will require a 45° conical flank tape wrapped at a 20° ply angle and a chop molded nose, as shown in Figure 2. A key feature in Fig. 2 is the preferred orientation of the chopped squares. Drawings of a scaled Pioneer Venus probe design are provided in Figures 3-5. They feature an adhesively bonded butt joint between the nose and frustum. The adhesive used by the Galileo Mission was a carbon filled (35%) Dow Corning silicone.[5]

[5] Brewer, R. A., Brant, D. N., AIAA-80-0358

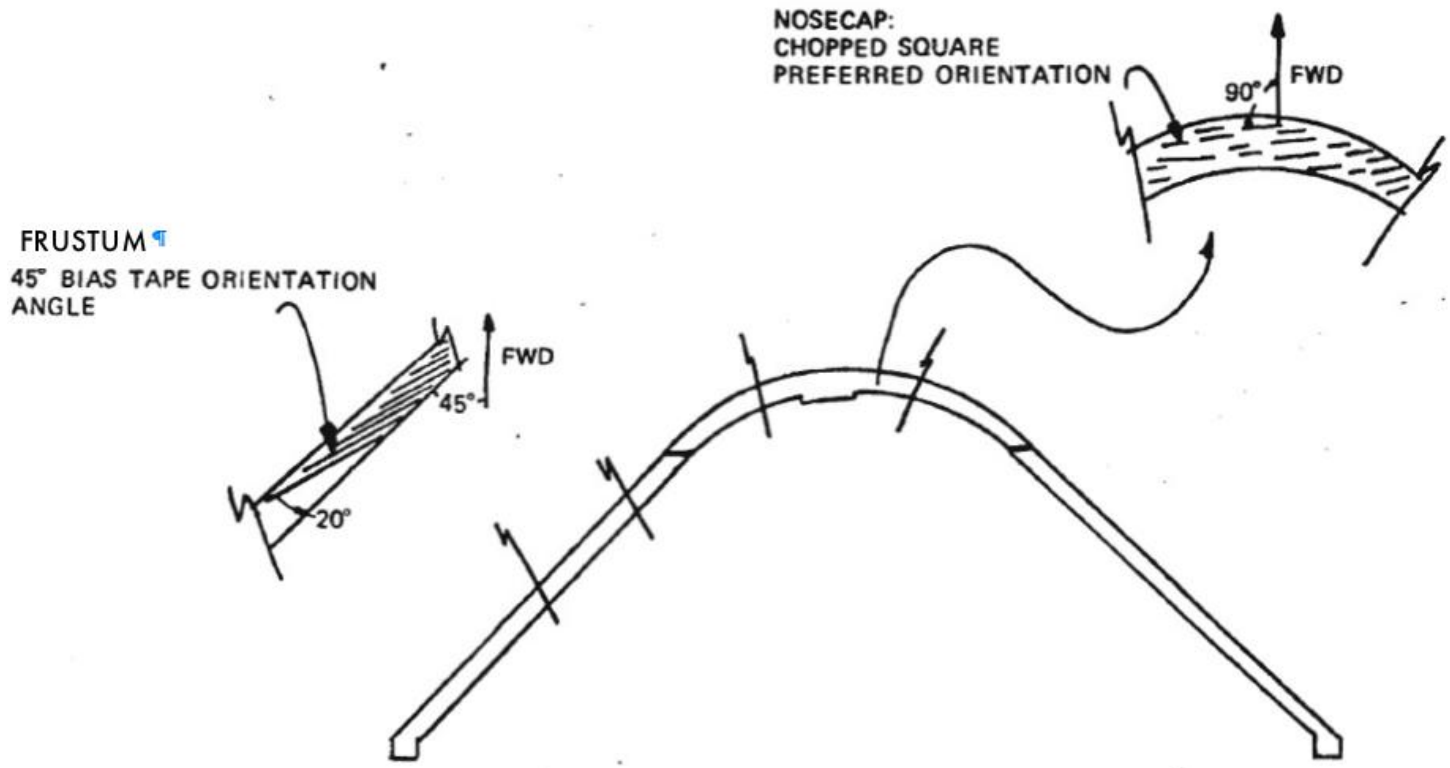


Figure 2 – Illustration of tape wrapped frustum and chop molded nose cap.

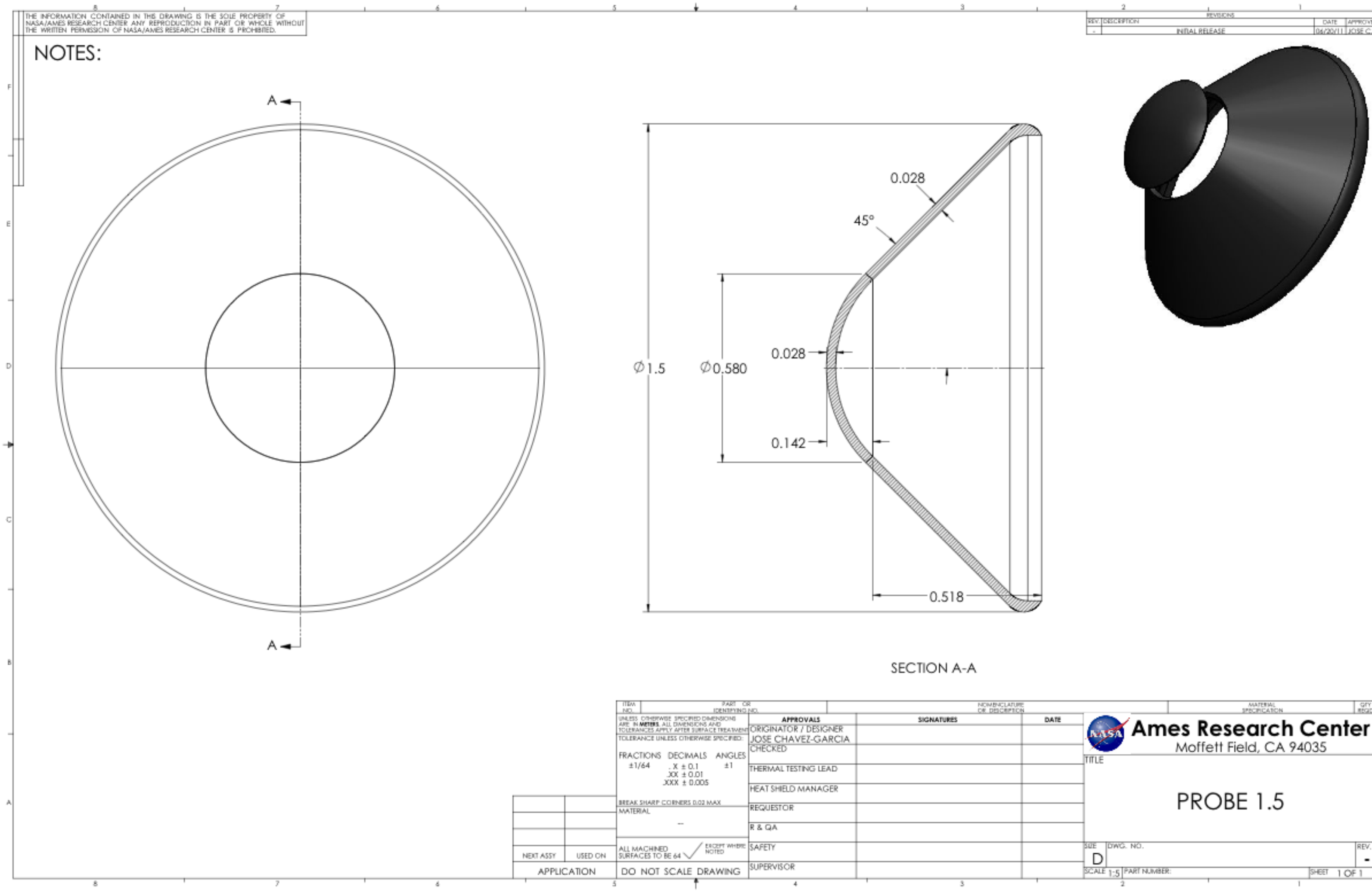


Figure 3 – 1.5 meter Pioneer Venus probe design.

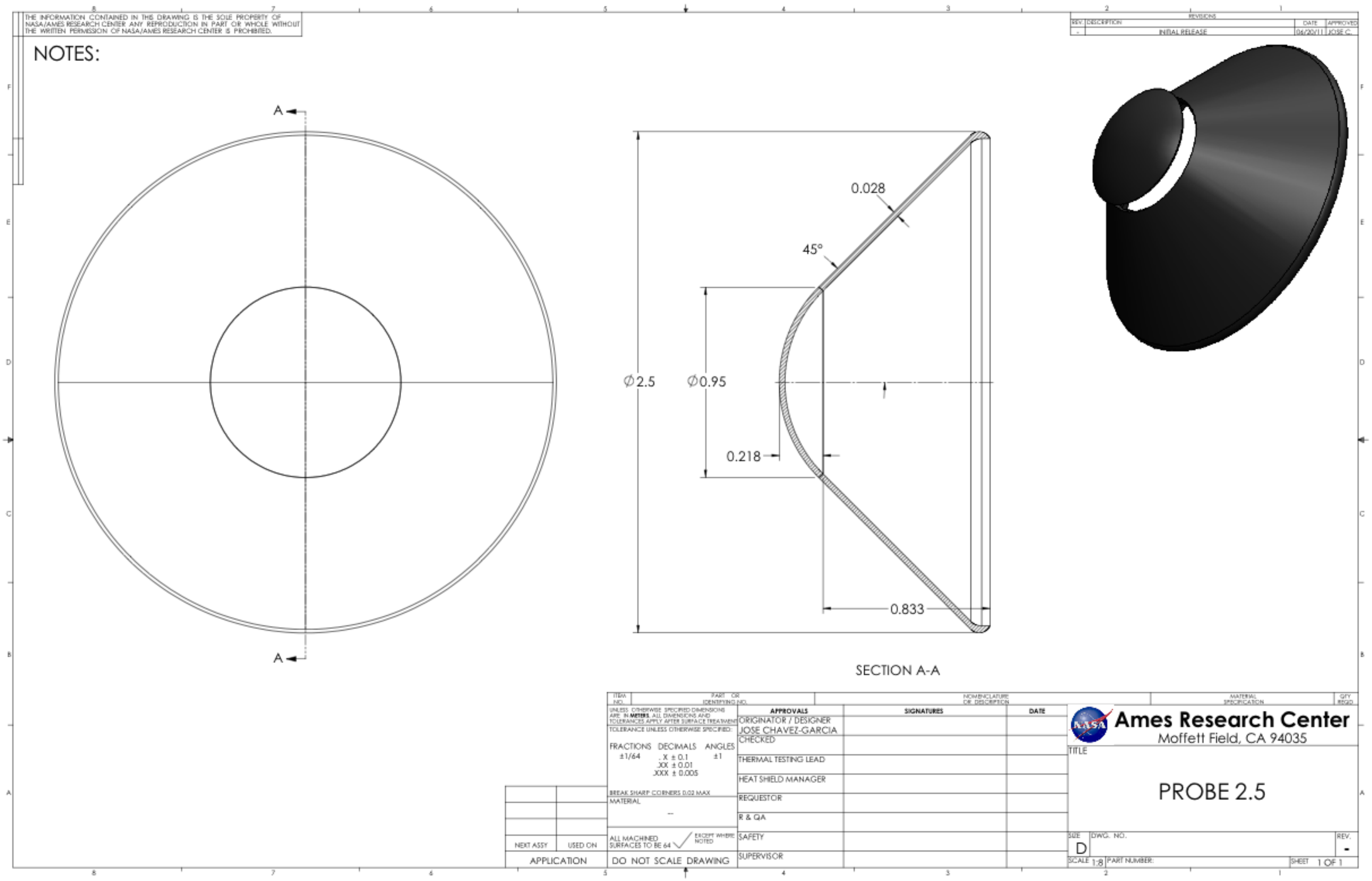


Figure 4 – 2.5 meter Pioneer Venus probe design.

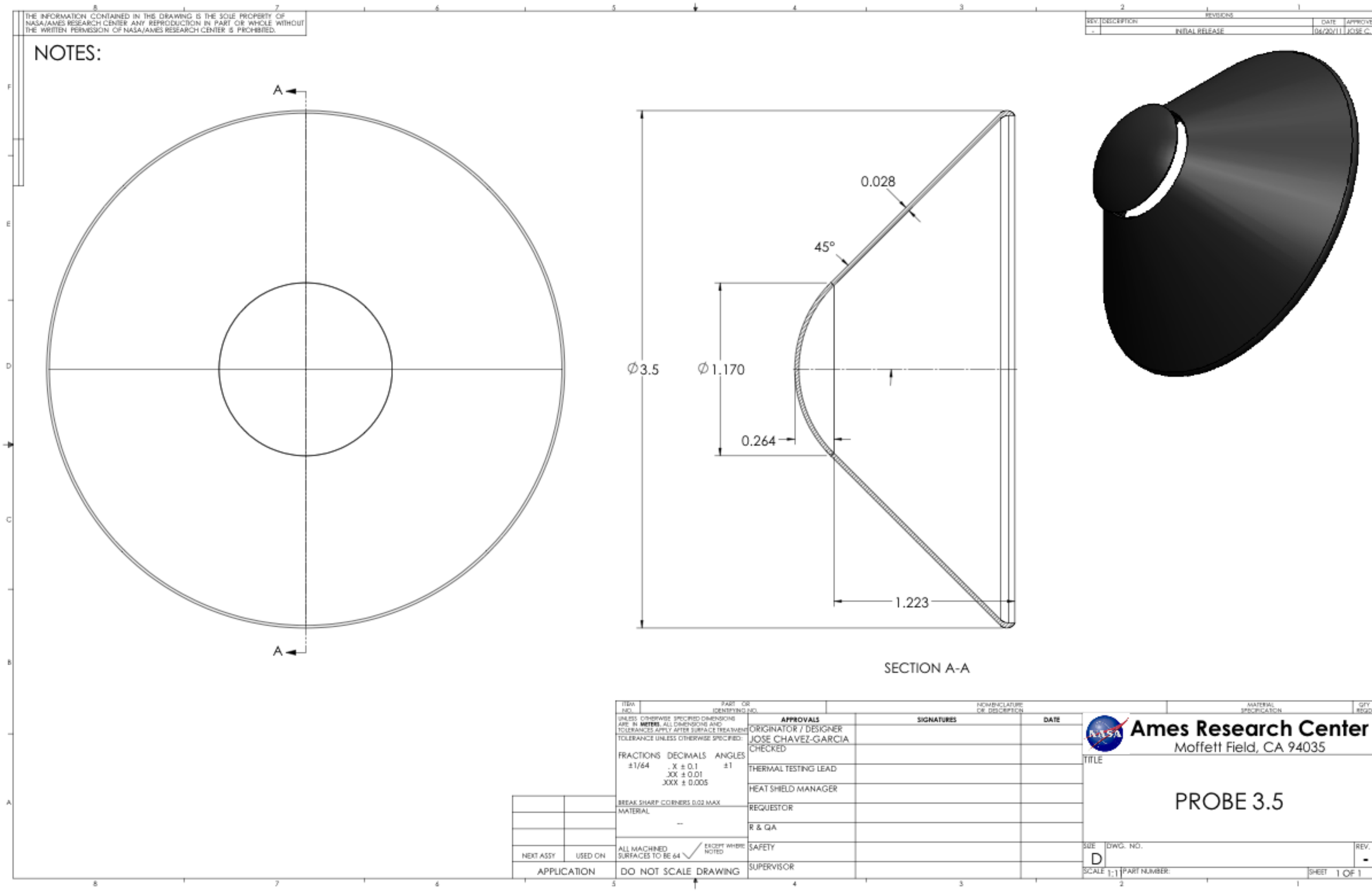


Figure 5 – 3.5 meter Pioneer Venus probe design.

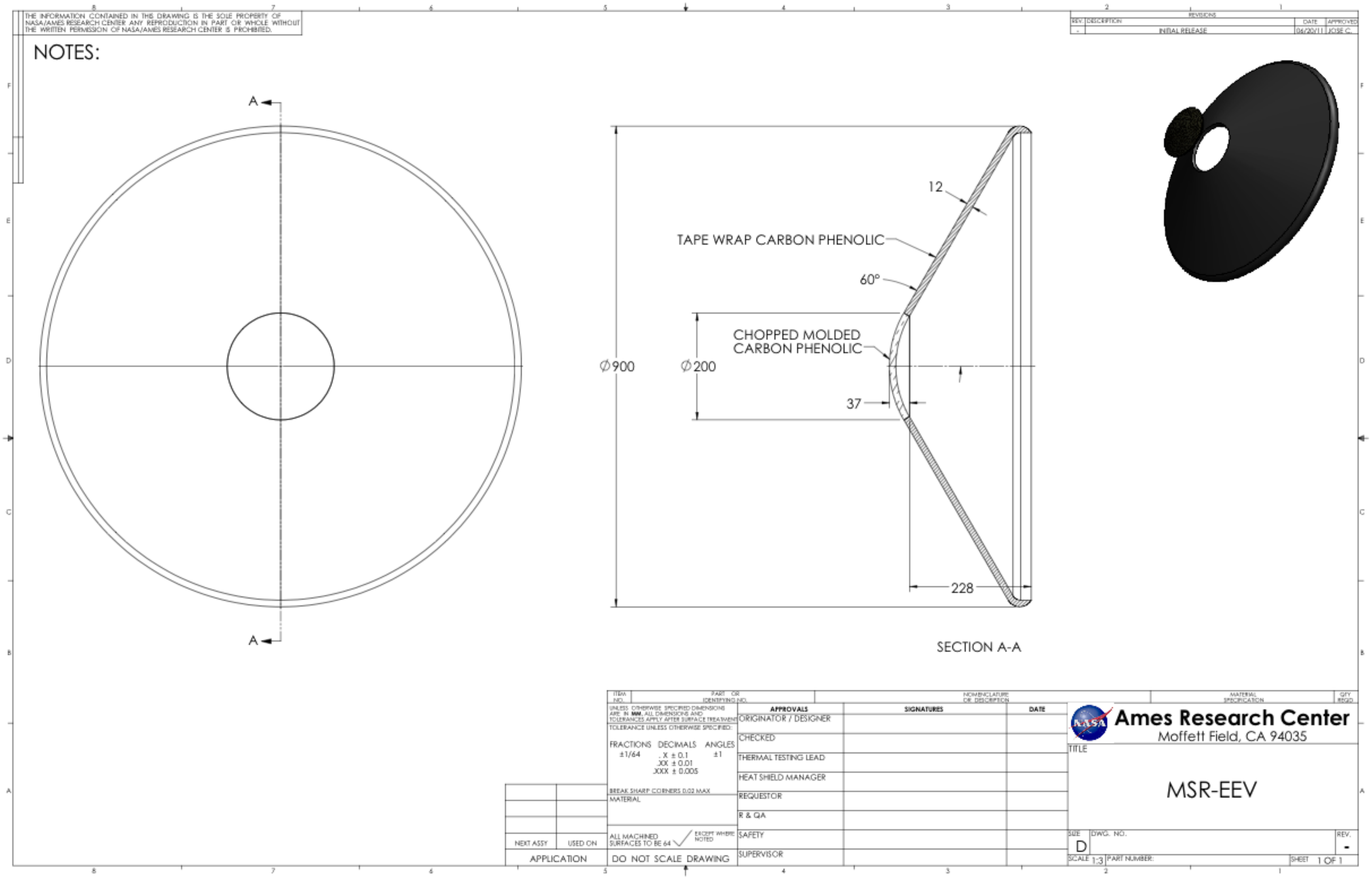


Figure 6 – Mars Sample Return probe design.

Blunt-cone heat shields required by NASA with dimensions less than 1.5 meter base diameter (such as that for Mars Sample Return) will require a 60° conical flank tape wrapped at a 20° ply angle and a chop molded nose, as shown in Figure 6.

Keeping both of the proposed TPS design concepts in mind, develop a Detailed Heat Shield Implementation Plan that covers the following topics:

1. Material Fabrication and Qualification
2. System Manufacture and Assembly
3. Heat Shield Certification, Inspection and Quality Assurance
4. Requirements for Carrier Structure and Heatshield Assembly
5. Risks and Risk Mitigation
6. Long Term Schedule and Cost

Please cover the above topics for each of the heatshield designs shown in Figures 3 through 6 (Pioneer Venus and MSR designs). Detailed descriptions of the requested DHIP topics are provided in the following pages.

Consider both heritage CP development (with NASA-supplied CCA3-1641b) as well as alternate CP development. For this exercise, for the heritage development, we shall constrain it to an MSR-sized heat shield (Figure 6) and focus on CMCP redevelopment. The objective is to understand the plan to redevelop as close to a heritage CMCP manufacturing process as possible and the amount of heritage material required to certify that process. Consider and explain the approach, for instance, whether to start with an alternate to establish the processes and then fabricate a limited amount of product from the heritage material, etc.

For alternate CP development, please then discuss the Pioneer-Venus designs (Figures 3 through 5). That would encompass the CP processing required for the entire heat shield (Nose and Frustum), utilizing alternate constituents (at least rayon precursor) and possibly alternate processes/architectures for the two parts.

There are multiple avenues that responders may take to this RFP. One would be as a “one stop shop” where the responder would not only manufacture the CP materials but would also deliver the final CP heat shield including attachment to the carrier structure and address joint designs between components. This is NASA's preferred approach. However, it is recognized that the RFP responders may just wish to be the provider of the CP materials and would look to a third party to act as the entity to perform heat shield integration. Given that the most critical aspect of this RFP is concerned with manufacturing high quality CP materials, it is acceptable that responders focus on the materials manufacturing and state that integration is beyond the scope of their capabilities and that function would be left to a third party, such as a prime contractor, to perform.

1. Material Fabrication and Qualification

Describe in detail the fabrication processes for each heat shield material component. All steps, such as chemical processing, mixing, shaping, curing, autoclaving, hot/warm pressing and vacuuming, shall be included. The identification of when and how all the constituents/ingredients are introduced into the process for each heat shield material component shall also be described. Describe how and when material/part testing will be performed and when results will be provided to the government. Include any processes utilized to achieve variable TPS material thickness or density. Estimate the time needed to create the heat shield material as a function of size (i.e., volume or acreage area). Will test units need to be manufactured, to evaluate scale-up processes?

Provide the list of raw materials including the percentage that each material comprises of the assembled heat shield as well as the time required to acquire each material. Address the limitations of current production techniques and discuss any changes that will be required to fabricate material for MDUs, EDUs, and final flight article heatshields.

Describe the process used to qualify all materials used in the manufacture and assembly of the heat shield. This description should include the process used to develop the initial material specifications and the plan to update them. Identify the physical and chemical properties that will be tracked, and discuss the expected variability within a material lot and reproducibility between lots. Describe the planned acceptance testing for the materials.

Describe in detail the availability of all raw materials, both presently and projected for the future, necessary to produce CP heat shield materials.

2. System Manufacture and Assembly

Describe in detail the manufacturing and assembly process for the heat shield system. All steps, such as chemical processing, mixing, shaping, curing, hot/warm pressing, autoclaving, vacuuming, machining and fastening, should be described. Discuss engineering solutions to ensure proper density, cure and absence of voids in the full scale heat shield.

Specific processes for attaching full-scale heat shield materials to the carrier structure should be discussed in detail. Present the geometric layout of all heat shield components, such as heat shield segments, and the sequence in which they must be assembled. Specifically discuss the system manufacturing issues with respect to sectional units (for gaps, seems, joints, etc.), MDUs, EDUs, and eventual flight articles, and note any differences between the processes for these different units.

Estimate the time needed to fabricate heat shield segments as a function of size (i.e., volume or acreage area). Identify any specific heat shield diameter/size/shape for which development and/or manufacture becomes problematic. Describe limitations of current production techniques or equipment and discuss any changes that will be required to permit fabrication of additional coupons, sectional (joint, gap or seam) units, MDUs, EDUs, and full-scale flight article heatshields. Provide a start-to-finish estimate for the amount of prepreg required to fabricate TWCP and CMCP parts (as described in Figures 3 through 6 and in the drawings posted on XEROX DocuShare) ranging from 1 to 3.5 m in diameter; include in the estimate machining wastage and material that would be removed for “tag-end” testing.

Describe currently available resources, staffing, manufacturing infrastructure, facilities and relevant partnerships. Discuss necessary infrastructure changes including the addition of facilities, fabrication equipment, personnel or other resources needed to deliver additional coupons, sectional units, MDUs, EDUs and flight article heatshield units according to the presently described schedule. If there are costs associated with retention of resources for long durations, specify them.

3. Heat Shield Certification, Inspection and Quality Assurance

Present a preliminary certification plan for the heat shield using the proposed materials and design. This plan should include a description of the analyses and tests needed to demonstrate such characeristics as:

- Density is consistant throughout the part
- NASA TRL requirements have been satisfied, etc.

Include specific discussions on the testing needed for interface elements such as gaps, seams, joints, seals, attachments and penetrations (if any). Include the anticipated role of material specifications in certification. Address how specification requirements will be verified.

Describe a proposed methodology for instrumenting the heatshield. At a minimum, in-depth thermocouples in the thermal protection material should be discussed. Past experience with instrumentation of the thermal material and other components should be presented. Impacts to the proposed manufacturing process and schedule due to the inclusion of various instrumentation elements should be documented.

Describe proposed Non-Destructive Evaluation (NDE) approaches for the heat shield, including minimum size voids or defects that are detectable by the proposed approaches, and justification for heat shield material design tolerance for voids as large or larger than the NDE detectable minimum. Include a discussion of the inspection of the various interface elements such as gaps, seams, joints, seals and attachments.

Discuss the inspection of coupons, sectional units, parts, sub-assemblies, MDUs, EDUs, and the full-scale flight article heatshields. Describe the actual facilities and equipment that will be used to perform these acceptance tests (prior to delivery) and any current limitations on available infrastructure. Include a discussion of inspection at each step of the installation sequence.

Describe the proposed methodology for repair and/or replacement of components that fail inspection due to material discrepancies, manufacturing defects, or damage. Describe if the repair processes are limited to being performed at the manufacturing facility or if the repair be performed at an integration site if needed and describe the limitations of field repair as compared to repair at the manufacturing site.

Provide a comprehensive description of the proposed quality assurance (QA) processes to be applied throughout development and to the full-scale flight articles. Describe the processes recommended for tracking the material qualification from coupon scale through full scale production. Identify current QA procedures for materials used during production, for manufacturing processes, and for engineering specification. Also discuss the quality status of facilities, tools, and other infrastructure and resources. Characterize the current QA status of the proposed thermal protection material(s) and system. Discuss how these procedures will be modified for MDUs, EDUs and flight article heatshields.

Describe current and/or recommended approaches to limit exposure of personnel to hazardous or toxic materials, vapors or fumes during handling, tests and inspections of material coupons, Local Design Demonstration Units (LDDUs) or MDU. Identify all potential hazardous or toxic sources, and conditions which result in exposure.

4. <u>Requirements for Carrier Structure and Heatshield Assembly</u>
Describe the expectations/requirements for the dimensional accuracy, surface smoothness, bonding performance, thermal expansion and structural stiffness of the heatshield attachment support structure for use in MDUs, EDUs and actual flight articles. This structure may be metallic,

composite, or a combination of the two. Please provide an assessment of the implications of the various support structure material options for the TPS material and/or attachment approach.

Describe the method of bonding to the heathshield to the metallic or composite substructure. Describe the method of machining the joint between the TWCP and CMCP sections. Also, suggest any alterate joint designs that may be viable.

5. Risks and Risk Mitigation
Discuss any identified risks for TPS manufacturing. Address issues associated with the thermal protection material(s) alone, and those associated with system integration. Characterize the risks by estimating their likelihood and consequence on a 5-point scale. Propose appropriate mitigation actions for each risk. Anticipate any OHSA imposed limitations on Rayon or heat shield manufacturing that can impact materials or TPS performance.

6. Long Term Schedule and Cost
Provide a timeline and cost estimate for delivering additional coupons, sectional units, MDUs, EDUs and full-scale flight-ready heatshields. Include detail for all fabrication and quality assurance activities discussed in this implementation plan. Discuss schedule challenges or critical paths in production processes that may require infrastructure or resource updates. Discuss the possible production rate for multiple articles. This section should focus on the schedule for maturing the manufacturing from the end of this contract to the various sized heat shields described above, MSR sized and heat shields in the size range from 1.5m to 3.5m. The objective is to understand any cost and schedule drivers that arise as a function of heat shield size and any unique drivers when comparing heritage redevelopment versus alternate CP development.

3.4 FORMAT

Electronic format (Microsoft® Word)

1. **DR NO.**: DR-002

2. **TITLE**: FM 5055 Acceptance Specification Review

3. **DATA PREPARATION INFORMATION**:

3.1 **SCOPE**

This FM 5055 Processing and Acceptance Specification seeks to establish the NASA requirements and mission assurance provisions for rayon based carbon fabric reinforced phenolic prepreg for use in fabricating carbon phenolic heat shields for NASA applications. Draft acceptance criteria were initially developed as part of this specification; however, the suggested criteria may be outdated or inconsistent with actual processes. The contractor(s) selected for the coupon and/or heat shield fabrication shall review and modify this specification as necessary to produce composites of the highest quality consistent with the contractor's selected process(es) and experience base. NASA retains final approval of the specifications to be used.

3.2 **APPLICABLE DOCUMENTS**

- FM 5055 Material Acceptance Specification (Appendix A)
- GE Spec S0060-01-0076, 3 November 1978
- GE Spec for Prepreg: GE R6537 Carbon Fabric Materials (prepreg)

These documents are ITAR restricted. See instructions in the RFP on how to access these documents.

3.3 **CONTENT**

The contractor shall review and modify the proposed FM 5055 Acceptance Specification (Appendix A) to verify that it is consistent with the contractor's selected process(es) and experience base. Review of the specification shall include a modified copy of the FM 5055 Acceptance Spec along with a brief report highlighting the proposed changes and explanations for the proposed changes. Review of the FM 5055 spec and summary report is due at the end of contract.

3.4 **FORMAT**

Electronic format (Microsoft® Word)

APPENDIX A – PROPOSED FM 5055 MATERIAL ACCEPTANCE SPECIFICATION

(This document is ITAR. See instructions in the RFP on how to access the complete document.)

SUMMARY

While specifications exist for the space shuttle rocket nozzle carbon phenolic, the entry environment and mission requirements for entry grade heat shield applications are quite different. A specification specifically tailored to heat shield applications is warranted. Previous efforts in developing a heat shield specification for rayon based carbon phenolic were performed under the Mars Sample Return Earth Entry Vehicle project in 2001 and documented in reference (i) the bidder's library. The major finding was that a combination of existing specifications for rocket nozzles and entry heat shields could meet the requirements of the MSR EEV project. The current specifications are the Marshall Space Flight Center Specification for carbon phenolic, designated MSFC-SPEC FM5055B, the General Electric heatshield specification (document S0060-01-0076), and the Galileo prepreg spec (document GE R6537 Carbon Fabric Materials). Of particular importance to HCP development are prepreg processing and acceptance criteria, which we suspect will require special attention in the forthcoming development effort too. The specification documented herein is based largely on the MSFC-SPEC FM5055B but includes elements from the GE R6537 specification. Acceptance testing is also defined and the criteria listed within this document.

If CMCP option is selected, then the Contractor shall provide a draft version of DR-002 (Updated Material Acceptance Specification) for NASA review and acceptance prior to fabrication of the CMPC billet(s).